



## Effect of cryogenic treatment on microstructure and properties of D2 tool steel

Villa, M.; Devos, C.; Hansen, M.F.; Lee, S.; Somers, M.A.J.

*Publication date:*  
2018

*Document Version*  
Peer reviewed version

[Link back to DTU Orbit](#)

*Citation (APA):*

Villa, M., Devos, C., Hansen, M. F., Lee, S., & Somers, M. A. J. (2018). *Effect of cryogenic treatment on microstructure and properties of D2 tool steel*. Abstract from 25th Congress of International Federation for Heat Treatment and Surface Engineering , Xian, China.

---

### General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

# Effect of cryogenic treatment on microstructure and properties of D2 tool steel.

M. Villa,<sup>1</sup> C. Devos,<sup>1,3</sup> M.F. Hansen,<sup>2</sup> S. Lee,<sup>1</sup> M.A.J. Somers<sup>1</sup>

1. Technical University of Denmark, Department of Mechanical Engineering, Building 425, DK 2800 Kgs. Lyngby, DK

2. Technical University of Denmark, Department of Micro- and Nanotechnology, DTU Nanotech, Building 345B, DK-2800 Kgs. Lyngby, Denmark

3. Now with: Safran Aero Boosters, Route de Liers 121, 4041 Herstal, Belgium

## Abstract

Intentional treatment of tool steels at cryogenic temperature has been reported to improve the mechanical properties, among which the resistance to wear. The mechanisms responsible for this improvement remain unexplained, despite various hypotheses. Literature data for D2 tool steel is extensive, wherefore this steel is the most promising candidate for additional investigation. In the present work, D2 steel was subjected to various austenitization treatments, followed by various cryogenic treatments and tempering treatments. The material's microstructure evolution and properties were investigated with synchrotron X-Ray Diffraction, scanning electron microscopy, vibrating sample magnetometry, hardness measurement and tribology tests. Data allows for a comparison to existing theories and to identify their shortcomings.

Austenitization treatments were performed at 990°C for 30 or 60 minutes and at 1030°C for 30 minutes. Cryogenic treatment consisted of: (1) immersion in boiling nitrogen followed by re-warming in water; (2) immersion in boiling nitrogen followed by storage in boiling nitrogen for 29 hours or 72 hours prior to re-warming in water; (3) cooling to boiling nitrogen temperature at a rate of 0.25°C.s<sup>-1</sup> followed by re-warming to room temperature at the same rate, interrupted by storage of the material 24 h at various temperatures in the range from -193°C to -33°C. Tempering consisted of: (a) two cycles at 250°C for 2h; (b) two cycle at 600°C for 2h; (c) continuous heating to 677°C at a rate of 0.1°C.s<sup>-1</sup>. In-situ Synchrotron X-Ray Diffraction analysis was applied to evaluate the evolution of the microstructure during tempering. Scanning electron microscopy was used to obtain information on the carbide populations and, more generally, on the microstructure of the material versus treatment conditions. In-situ magnetometry was applied to follow the austenite-to-martensite transformation as well as the evolution of magnetic hardness during cryogenic treatment. Finally, hardness and tribology tests were used to obtain an indication of the material's properties and performance for the treatment conditions.

Data showed that a certain fraction of retained austenite was always present in the material prior to tempering, independent of the austenitization conditions and cryogenic treatment applied. Cryogenic treatment reduced the fraction of retained austenite in the material. The austenite-to-martensite transformation during cryogenic treatment (BNT) was found to be partially athermal, partially time dependent. A cryogenic cycle including prolonged storage at boiling nitrogen temperature reduced the fraction of retained austenite in the material, even though isothermal transformation at BTN was negligible. The isothermal martensite formation was accompanied by magnetic softening, which can be interpreted in terms of rejection of C from solid solution in martensite, supporting previous claims in the literature. Immersion in boiling nitrogen followed by immediate re-warming in water was sufficient to modify the response reaction of the material to tempering as well as its resistance to wear after tempering.